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The opportunity to discuss the Studies on Household Sewage Disposal Systems with you is welcome indeed. As some of you may know, these studies are being conducted at Cincinnati by the Public Health Service as a cooperative project under the programs of the Administrator, Housing and Home Finance Agency, and the Public Health Service. A progress report, Part I of the Report on these studies, has been published and covers the work done during the period, November 1946 to June 1948. Due to lack of funds, the project was discontinued in June 1948. However, the studies were resumed in January 1949 and have continued to date. Part II of the Report, covering the six-month period, January to July, 1949, is in the process of being published; and we hope that it will be available for distribution soon.

The proposed Studies on Individual Household Sewage Disposal Systems are intended to include methods other than the conventional septic tank-soil disposal field. However, as the most pressing problems at present are involved with this type of system, most of our effort has been devoted to the septic tank and to the related soil absorption field. So far as practicable, the individual experiments which we undertake are oriented with immediate needs in the field as various problems come to the attention of the two agencies.

I am sure that you are well aware of the fact that there is an appalling lack of basic information concerning the various parts of these small systems. The seriousness of this lack of basic information can be appreciated when

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we realize that the individual home sewage disposal system is an important segment of American sewerage practice. The necessity for an individual system for disposal of water-borne sewage originates in our demand for running water and the conveniences of modern plumbing. There was a time when modern plumbing was an advantage peculiar to city living. That is no longer true. With the availability of public water supplies in fringe areas, and of electricity and modern transportation in rural and semi-rural areas, where often community sewerage systems cannot be provided economically, the demand for modern conveniences is easily met. The availability of these modern facilities in rural and semi-rural areas has made it possible for many people to enjoy uncrowded living, and the trend toward residential development--and septic tanks--in outlying areas is not likely to diminish.

Hence, not only is this field already large in size but the recent trends in home building indicate tremendous growth in this sector of our sewerage practice. Consider for instance, on the basis of figures as of 1945, about 22,000,000 persons in this country were served by refined treatment processes; that is, processes which furnish treatment beyond plain sedimentation, and are comparable with the individual septic tank-soil absorption system. In comparison, the individual household septic tank-soil absorption system serves an estimated 17,000,000 persons. In terms of numbers of plants the individual household plant represents some 4,400,000 installations, as against 5,700 municipal sewage treatment plants in this country. This is of some consequence to the administrative authorities, particularly in the volume of inquiries and complaints to be handled. As for current trends, it was estimated not very long ago that of the F.H.A.-involved residential building going on over the country, about 40 per cent of the installations called for individual sewage disposal systems. In an eastern F.H.A. region 90 per cent of the new homes were to use individual systems!

This field is not new. The use of the individual septic tank system dates back some 70 years in this country. Unfortunately it was given little serious attention, from the standpoint of development of the facts of its behavior, until recently. Because of this, the technical foundation was found rather shaky; there was an abundance of opinions on various designs and behaviors but little that was supported by factual investigation.

Organized control over installation of residential sewage disposal systems was known in only a quarter of the local health units over the country fifteen years ago. Only about 40 per cent of the systems installed to date have been put in under organized control. This is part of the picture. The operating side of the problem is also important and there appears there a weakness in the failure to advise householders of servicing responsibilities and in the lack of regulation of cleaning services. This is rather a peculiar field of sewage treatment from the operating standpoint in that we expect the householder, who is not particularly experienced nor even interested in sewage treatment, to be the operator. Therefore, technical improvements in design and installation will help but will fall short of the goal if attention is not given to operating and servicing problems.

As you are familiar with the general features of the usual septic tank-soil absorption system, I shall not take time for elemental description. However, I want to emphasize that the septic tank is but one part of this system of disposal. Its functions are significant only from the standpoint of its relation and behavior in the system as a whole. You will hear quite often remarks on the performance of this or that septic tank, without a qualifying explanation of the disposal of the waste beyond the tank. The danger in attaching significance to such claims may be readily understood when one reflects that a septic tank which may discharge to a ditch or gravel formation may

appear to operate satisfactorily for many years; whereas, the same tank in a system of disposal to soil absorption might fail miserably in a short time under similar circumstances of attention, or more properly, the lack of attention.

Coming now to the studies, we may say that the purpose of the studies is an attempt to find out what happens in the residential sewage disposal system and its parts under various loading and environmental circumstances. With such information it should be possible to develop recommendations for design standards and servicing procedures which are fundamentally sound because they are based on facts. A staggering variety of experiments and investigations have been conducted by the Staff at Cincinnati. Our efforts have been expended along three major lines of endeavor: Field Investigations, Soil Studies, and Studies of Septic Tanks and Related Appurtenances.

Field investigations supplement our laboratory investigations and also provide valuable information which cannot be gained under laboratory conditions. For instance, while comparative performance of tanks may be observed in the laboratory the use of municipal sewage does not enable us to observe the rate of scum and sludge accumulation under household circumstances.

Other variables can be observed only in the field. The waste to be disposed of results from living habits in a particular home. It is subject to the variations in quantity and composition peculiar to that home and is not a composite of the wastes of many homes such as we would have in municipal sewage. Therefore, while averages are of interest, design must take into consideration the magnitude of variation to be expected when dealing with individual installations. From our field investigations we have metered water supply data from residences on septic tank systems. We are using this data as a guide to the daily volumes of waste until data on waste gagings become

available. On the average the summer water use was 49 gallons per capita per day and the winter use 39 gallons per capita per day. We would expect the average waste volumes to be within these limits, probably close to the winter figure. The variation is wide, however. On winter water use, individual residences range from as low as 8 gallons per capita per day up to some 150 gallons per capita per day. The summer spread is even greater, ranging from 8 to 226 gallons per capita per day. As you may appreciate, the habits of the particular household will affect the character of the waste as well as the volume. Consider in this connection that some homes have garbage grinders, water softeners, or various types of washing machines; also, practice varies in the use of soaps and detergents. We cannot ignore these wide variations, rather we must orient our thinking so that design will be based on the more severe cases rather than some hypothetical average.

During the period February 1947 to July 1948, 300 single household septic tanks in normal operation in nine areas over the country were examined by two-man engineer-laborer teams. Sludge and scum accumulations measured in these tanks, after various periods of normal household use, were useful in determining trends and in serving as a rough yardstick of performance as measured by solids retention. From graphs of average per-capita scum and sludge accumulations per year, against time in service, rates of residual accumulation appear higher during the first six years of service. The residual accumulations appear, also, to increase as per capita tank capacity increases. For tanks in the 125 to 175 gallon per-capita liquid capacity group, the unit accumulations approximated the average accumulations for tanks of all capacities. Tanks with per-capita capacities smaller than 125 to 175 gallons tended to accumulate less, while larger unit capacity tanks tended to accumulate more solids than the average.

These examinations of the data were originally made on a per-person basis. While it is possible to do this in examining systems where the person loading history is available, we find that the later application to design always comes back to bridging the gap between a residence of known history and a proposed residence for which its future occupancy is indeterminate. The one thing we do know is the physical size of the house, that is, the number of rooms, or bedrooms. We have, accordingly, re-examined our sludge and scum accumulation data on the basis of the number of bedrooms. Furthermore, if the tank is to operate successfully for most homes it must be designed from curves enveloping some of the more extreme cases. In this study we determined by statistical methods the sludge and scum accumulation rates necessary to envelop 19 out of 20 cases observed in the field. These rates are as follows:

No. of Bedrooms	Sludge	Scum
2	$Y = 12.45 + X$	$Z = 5.05 + .56X$
3	$Y = 11.80 + .48X$	$Z = 7.18 + .14X$

Where X equals the period of accumulation in years

Y equals the sludge accumulation in cu. ft./bedroom

Z equals the scum accumulation in cu. ft./bedroom

These are roughly two to three times the average accumulation rates.

There is evidence contained in the field data collected to show that the sludge storage capacity of a tank is influenced by the penetration of the outlet as well as the total liquid capacity of the tank. It was observed that sludge levels tended to reach a point about one foot below the bottom of the outlet device as a maximum. We have called this distance between the top of the sludge and the bottom of the outlet device "clear space." More will be said about the concept of a minimum clear space in the discussion of our laboratory results.

Concerning scum accumulation, it was found that approximately three-quarters of the scum accumulated below the water line. Furthermore, a comparison of the sludge and the scum accumulation formulas illustrates that the portion of scum accumulating below water line is approximately 30 per cent of the total scum and sludge accumulating below the water line. With these figures, if we assume a maximum sludge accumulation to about one foot below the bottom of the outlet device, and allow some three inches between the bottom of the scum and the bottom of the outlet to prevent scum under scour, we can rationally proportion the outlet baffle or device to provide a balanced design for sludge and scum storage.

While discussing sludge and scum accumulation, it might be well to discuss the matter of tank cleaning. To the best of my knowledge there is no way to avoid the removal of accumulated solids from a septic tank if efficient operation is to be maintained. I am inclined to feel, however, that the setting of some blanket cleaning period, whether it be three or five or some other number of years, does not answer this problem. As you may have gathered from my previous remarks, there is considerable variation between individual installations in the rate at which they accumulate sludge and scum. In order to safeguard the high-accumulation installations, a short cleaning period would severely penalize those systems which could safely run several times as long without cleaning. A logical solution would depend on periodic inspections of individual tanks by the home owner or others so that cleaning could be accomplished as necessary. We have attempted to develop some means whereby a sludge level might be gaged, within practical limits, with a simple home-made device. A weighted string and a roughened stick did not appear to work at the laboratory. However, a long stick wrapped with a piece of towelling and left in contact with the tank contents several minutes showed promise.

This device is being tried in the field. An attempt to develop something similar with which to locate the bottom of scum in relation to the outlet penetration is also being made. In such a case the householder, or possibly a commercial service by periodic gaging, say at yearly intervals, might effectively keep a check on the tank.

A few words on the freezing aspects of household sewage disposal systems may be of interest to this group. From a survey of the literature, including the septic tank system recommendations of eleven northern states, several case histories, unpublished information from Canadian investigators, and a poll of northern plumbers, it appears that a carefully constructed shallow household system, with gravel-packed tile lines, and insulation of pipes under driveways or other surfaces usually cleared of snow, will rarely freeze if kept in continuous operation. This does not necessarily apply to non-household systems, such as those serving country schools. Investigation of country school systems freezing in Calhoun County, Michigan, in 1948, revealed unusual conditions when compared with household systems. Longer periods of daily and weekly idleness of the system were encountered, and no hot water was being used. There were no reports of household system freeze-ups at that time in the same vicinity.

At the present time there is one field investigation team engaged in a study comparing the behavior of systems receiving sewage and ground garbage wastes, with others receiving no garbage. This opportunity was offered in Duval County, Florida, wherein, in the Jacksonville area, some 42 installations receiving ground garbage have been in operation for about three years. These units are being compared with similar units in the same area which have received no garbage and have been in operation over the same period of years. In connection with this same investigation, practical methods of measuring sludge and scum with home-made devices are being tested against our laboratory instruments.

This team has been in the field for only a short time and as yet the data are not completed to the point where a true analysis can be made.

Turning now to the study of septic tanks and related appurtenances under laboratory conditions, I wish to reiterate that the major objectives in our tank studies, as well as all of our studies, are to determine the factors which influence the behavior of a septic tank, to evaluate those factors, and to pass that information on so that intelligent regulations and administrative decisions can be made. Many of the individual experiments which we undertake could lead to studies lasting a lifetime. However, as our project is one of practical as well as basic research, it becomes necessary for us to discontinue a study as soon as we are certain that a firm trend has been established. For this reason many questions of deep interest must go unanswered or be deferred to a later date when more pressing problems have been solved.

At this time it might be well to emphasize again that the septic tank and tile field supplement each other as integral parts of the same system. One physical characterisitc necessary for the proper performance of the distribution field is the percolation quality of the soil or the ability of liquids to move through it. As no rapid practical means of improving or restoring soil percolation is known, it becomes the function of the septic tank to protect the original percolation rate of the soil. This function is accomplished by trapping and holding a large percentage of the suspended solids, and by subjecting raw sewage to digestive processes in the tank.

Full scale septic tanks under observation in our laboratory are dosed with fresh sewage from a combined sewer serving a nearby residential district. Raw sewage to be used is pumped to an elevated conical shaped dosing tank equipped with a stirrer. Approximately every two hours all tanks are dosed in rotation with an equal amount of sewage. Each day eight feeds are made

starting at 7:00 A.M. and ending at 9:45 P.M., seven days a week. The quantity of each feed varies to conform to a pattern of metered water use obtained from observations at the homes of several staff members. The rate of influent flow is manually regulated at 10 gallons per minute. All effluent is collected in individual receivers after each feed and sampled to make a larger composite sample for analysis. Routine solids, temperature and pH determinations are made on both the effluent and the raw sewage. Special determinations include B.O.D., dissolved oxygen, sulfides, grease, gas analysis and bacteriological examinations.

In the first phase of the study 18 full-size septic tanks were operated under parallel conditions for periods up to a year. Included were five single-compartment tanks of approximately 500 gallons capacity but of different shapes. Vertical and horizontal circular, rectangular, and oval-shaped tanks were represented. Under identical circumstances the suspended solids removals for all five tanks for the entire year ranged between 59 and 65 per cent. In other words, for the same capacity, variation in shape of the single-compartment tank had no appreciable effect on efficiency. The variation in depth was too small to be indicative of behavior under any radical departure from four feet, although it appeared from this study that a small variation, say half a foot, would make little difference. Depth studies are being conducted which I will discuss shortly.

Keeping the 59 to 65 per cent suspended solids removals of the five single-compartment tanks in mind, I want to discuss the performance of two multi-compartment tanks which were operated at the same time, under identical loading and sludge addition circumstances. These were a 550-gallon two-compartment, 36-inch diameter, vertical circular; and a 670-gallon four-compartment, 24-inch diameter, vertical circular tank. These tanks performed

at 78 and 84 per cent suspended solids removals for the year, roughly 20 points above that of the single chamber tanks. The difference in performance is more evident when considered from the effluent solids standpoint. For example, assume a 200 ppm suspended solids sewage, the roughly 60 per cent removal of a single-compartment tank would mean 40 per cent or 80 ppm passing out of the tank. On the other hand, the 80 per cent removal of a compartmented tank would mean 20 per cent passing out or 40 ppm in the effluent, or only one-half of the solids passing out of the single tank.

Tanks of capacity smaller than 500 gallons have been investigated also. While these started with reasonably good results, they appeared to reach their small sludge storage capacity quickly with an accompanying dropping off of efficiency. A seasonal cycle correlated with temperature changes was evident in the behavior of a single-compartment tank of only 123 gallons capacity. Efficiency was high during cold winter months with a rapid accumulation of sludge. Quality of the effluent deteriorated rapidly with the onset of warm temperatures in the early summer. For a period of ten weeks effluent from the tank contained more solids than the incoming sewage, and most of the winter's accumulation of sludge was lost. Performance during the remainder of the summer and fall was erratic and poor, but improved considerably with the onset of cold winter temperatures. Identical results were obtained when the experiment was duplicated by starting the tank in the summer. Compartmented tanks of small capacity produced the same results.

Several exploratory trials of tank inlet, outlet and inter-compartment flow appurtenances have been made. For the sake of obtaining some quick exploratory results these were run on the basis of detention time using uranin dye as a tracer. Ultimately, suspended solids performance trials must be carried through on promising arrangements. Concerning a tee inlet, baffled

sewer inlet and plain sewer inlet, experimental comparison on the basis above mentioned indicated that there was essentially no difference in the experimental detention time among the three inlets. There was, however, an indication of a slightly better flow pattern for the tee inlet, followed by the baffled inlet and the plain sewer inlet in that order. Operating two three-compartment rectangular tanks, one equipped with inverted U's between compartments, and the other, first with a 4-inch horizontal tank-width slot, and later with a 4-inch diameter hole, both submerged 12 inches to the top of the opening, it was found that ths slot at this position gave the same experimental detention time as a tee fitted single-compartment tank of equal capacity, and only half the detention time of the inverted U-equipped compartmented tank. Upon constricting the slot opening to that of a 4-inch diameter hole at the same depth, the detention period lengthened, but did not come up to that of the inverted U-equipped tank. These are, of course, at one position, and other locations are to be investigated. One experiment on outlets has been performed in which there was no essential difference in suspended solids removal from two identical tanks, one operated with a tee outlet and the other with a baffled tank-width weir. Other outlet experiments are under way, in connection with the depth studies.

The depth factor has been a topic of some interest. As you may know, the Joint Committee and many of the states have recommended a minimum liquid depth of four feet. As our earlier work did not cover this factor specifically, a set of four rectangular tanks of varying depths are being operated for this purpose. The four tanks are of equal liquid volume, 500 gallons, and have length to width ratios of 2 to 1. The liquid depths are $28\frac{1}{2}$, 36, 48 and 64 inches respectively. These are being observed over a range of sludge accumulations. Thus far, within the limits of our experiment, the variation in liquid depth

itself appears to have little or no effect on the suspended solids removals. I hasten to add, however, that this is not the whole story. There is some evidence from field observations that sludge accumulations tend to level off at a common distance below the bottom of an outlet. If the idea of a constant "clear space" bears out in the trials under way now, the inference would be that the deeper the tank the more sludge storage capacity it would have for the same total liquid capacity. As this bears on the frequency and expense of cleaning, it is of importance. Where environmental circumstances may indicate need for a shallow tank its smaller sludge storage capacity could be brought up to that of the deeper tank by increasing total capacity.

Another experiment run in conjunction with the depth studies and designed to shed further light on the subject of clear space has been completed. A 492-gallon horizontal cylindrical tank was filled with well compacted sludge and then dosed with raw sewage according to our established laboratory procedure. Solids were discharged from the tank and the sludge level dropped to a point about two-thirds of a foot below the bottom of the outlet baffle where it remained stationary during the cold months. With the warmer temperatures of spring and summer, the sludge line again dropped and leveled off at a foot below the bottom of the outlet device.

Some investigation of the behavior of a septic tank receiving ground garbage has been made in the laboratory. In this study two rectangular tanks, each identical in design and capacity--which was 500 gallons--were operated in parallel. The one received sewage only while the other received sewage plus daily additions of ground garbage from two homes of two and three occupants respectively. During a seven-month period of operation the garbage-sewage fed tank discharged less suspended matter than the tank to which sewage only was fed. However, during the next three months of the operation, the comparative

performance of the garbage-sewage fed tank fell off considerably. It is thought that the greater amount of solids stored in the garbage tank over the cooler winter months resulted in a greater increase in digestion activity at the higher spring and summer temperatures near the end of the run, which in turn caused the garbage tank to discharge more solids. Concerning digestion of the garbage solids, it is interesting that the pH's for both tanks were about the same, ranging around 7.3 and 7.5. The ratio of effluent volatile suspended solids to suspended solids for the garbage-sewage tank tended to be higher than that of the sewage fed tank. This higher ratio may indicate a comparatively greater proportion of raw or partly digested matter, as compared with the effluent from the sewage fed tank. If so, this may explain in part at least the soil clogging behavior of the garbage-sewage fed tank effluent as compared with that of the sewage fed tank, which I will touch upon later. As was mentioned before, we are conducting field investigations in Florida comparing the behavior of systems receiving sewage and ground garbage wastes, with others receiving no garbage. For the time being we feel that the 50 per cent increase over the tank capacity recommended for household wastes without garbage, recommended by the Joint Committee, F. H. A. and others, is a reasonable allowance. It is obvious that the solids load is increased considerably and that the period between cleanings will be materially shortened unless additional capacity is provided. Frequent cleanings are uneconomical financially, but there is also another factor to consider. Each operating period is accompanied by a breaking in and tapering off period during which tank performance is not at its best, and the net effect is lower performance in the long run. This, of course, is damaging to the tile field. Ample capacity is insurance at low cost.

Frequently we receive inquiries about the application of chemical or biological compounds to clean or condition septic tanks. While we cannot

attempt to test every commercial compound on the market, we have conducted experiments with some of the known active agents of these compounds. A few statements concerning our experiments with caustic soda may be helpful. In one of these cases the addition of 25 pounds of sodium hydroxide to a 455-gallon septic tank under laboratory observation caused an immediate rise in the effluent pH to 12.3 from its original value ranging about 7.3. For five successive days, the pH remained above 11.0. Digestion in the tank, as evidenced by the lack of gas bubbles, the lack of tank turn-overs, and a rise in the ratio of suspended volatile matter to suspended solids, stopped, or at least was seriously interfered with. Digestion in the tank was dormant for a period of twenty-three weeks during which time sludge accumulated at a rapid rate. Following the twenty-third week after the addition of caustic soda, digestion re-started accompanied by rapid gasification which produced a serious disturbance in the tank. Large quantities of suspended solids were discharged from the tank for a period of four weeks following this re-start of digestion. Caustic soda had an even more pronounced effect on soil cores which I shall discuss later. It is known that some of the so-called "septic tank cleaners" contain sodium hydroxide as the active agent. Yeast has been investigated as a possible seed material or starter for sewage digestion, and was found to have no merit. In my opinion a well-designed and properly maintained septic tank needs no props. This statement does not preclude the use of ripe septic tank sludge as a starter.

Many localities have become interested in the effects of discharging zeolite water softener regeneration wastes to the septic tank system. As you know, these wastes contain a high concentration of mixed salts of sodium, calcium and magnesium. Early bottle tests indicated that a 1.2 per cent solution of mixed salts inhibited digestion; and that this effect was reduced by mixing and flushing. A 2.4 per cent solution settled to the bottom of a full-sized

tank and failed to dilute in the bottom layers even under the influence of periodic sewage feeds. An experiment has just been completed in which, in addition to the regular feeds of raw sewage, once each week mixed salts were introduced into a 455-gallon tank in a manner designed to simulate the discharge of waste from a water softener. It was demonstrated that chloride concentrations built up to a high ranging from 1.0 to 1.2 per cent near the bottom of the tank during cold weather; however, the tank, for all practical pruposes, purged itself of salt with the advent of warm weather. In spite of high salt concentrations in the sludge layer, digestion seemed to proceed well at all times during this experiment. Further investigation revealed that sludge in the tank had become acclimated to a salt environment; and was inhibited little if any by a salt concentration of one per cent; while at the same concentration a normal sludge was strongly inhibited. Caution should be exercised in applying these results to a new installation or to one which has been cleaned and returned to service without seed sludge.

Before closing the discussion of laboratory septic tank studies, we have observed a general pattern of behavior which may be of interest to you. Based on suspended solids removal all tanks have shown a seasonal type of behavior. As a rule, during winter and spring, efficiencies register consistently high; with late spring or early summer accelerated digestion in raw or semi raw solids accumulated during the winter causes a severe disturbance in the tank and a corresponding loss of solids; after recovery from the initial upset performance remains erratic and relatively poor for the remainder of summer and fall. Seasonal variation is not as pronounced in compartmented tanks of proper capacity and design, leading to a more stable performance; however, sludge does move downstream from compartment to compartment during the period of early summer upset. Thus we must observe a tank during all three phases of operation before a true appraisal of its behavior can be made.

Turning now to the soil studies, the conventional septic tank system depends upon the soil distribution field for the ultimate disposal of the bulk of sewage it receives. The magnitude of the task we impose on the soil can be appreciated when we consider that the average rainfall in Virginia is approximately 45 inches annually; and the amount of effluent applied annually to a disposal field, based on current design, ranges from 240 inches for tight soils to 1,100 inches for porous soils. In some cases in the field over 2,000 inches were being applied.

A problem of immediate concern is that of devising methods whereby the soil absorption area required for any specific system may be quickly and accurately determined. A number of factors are concerned such as: clogging characteristics of septic tank effluent, volume of waste to be disposed of, climate, and most important, the absorption characteristics of the particular soil to be used.

In the 1920's Henry Ryon working in New York State developed a percolation test which has proved to be a useful tool. He developed an empirical relationship between the rate at which a soil would absorb clear water and the rate at which it would absorb septic tank effluent. Ryon's test and empirical relationship, with perhaps some slight modification, is apparently the basis for most of our present day soil absorption field recommendations advocated by the various control agencies.

We have investigated the Ryon test and are in a position to suggest some modifications which we believe to be improvements.

First, we would substitute a four-inch auger hole for the foot square dug hole now being used. Comparative tests employing a foot square dug hole, an eight-inch auger hole, and a four-inch auger hole in soils representing a wide range of rates and absorption characteristics have shown conclusively that,

in the same soil, there is no significant difference in the percolation rate as measured by any of these hole sizes.

Second, we suggest a more complete saturation of the soil before measuring the percolation rate. This is particularly true of clayey type soils subject to swelling as saturation proceeds. In experimental studies test holes were filled with water to a 12-inch depth. Measurements were made every 10 to 15 minutes for four hours. The holes were then filled and allowed to soak overnight and the test was then repeated over a four hour period the next day. That more complete saturation can be of practical concern is apparent when we consider the results of one of these experiments. This experiment was conducted in a Rossmoyne soil, and if the rate were calculated by averaging the first day's results and referring to the Joint Committee on Rural Sanitation table, an absorption area of 208 square feet would be required, and the site would be acceptable. If, however, the rate were taken over the last 30 minutes of the second day, the site would not be acceptable. This later case agrees with the performance of the soil under operating conditions. In this soil not one of a number of systems investigated was considered satisfactory. One system, about five years old, containing 300 square feet of absorption area and receiving toilet waste only from one adult and two children was found to be completely flooded with serious surface seepage occurring. This inspection was made in August, temperatures were high, vegetation over the field was lush and conditions in general were most favorable for successful operation.

Third, we suggest that the rate at the end of the test rather than the initial or some average rate be used. In making a percolation a large decrease may take place during the early part of the test. The magnitude of this decrease depends upon prior moisture conditions and characteristics of the soil involved. The decrease will be more pronounced if the test is started in a dry soil, and

is likely to be more pronounced in a clay-type soil than in a sandy-type soil. A plot of a typical percolation rate would demonstrate that the rates tend to approach a minimum asymptote as saturation proceeds. The lower rates obtained near the end of the test are undoubtedly more representative of soil behavior under tile field conditions.

Another suggestion, although strictly speaking not a modification of the Ryon test, is to make enough replicate tests to cover inherent variabilities in the soil encountered. The time and labor saved by using smaller test holes could be profitably employed in making these replicates. For a one hundred foot square area, probably four to six or more tests are necessary to obtain reliable design rates.

Soil clogging is a study towards which we are directing much of our attention. The empirical relationship evolved by Ryon was developed under the limited soil conditions of New York and under sewage characteristics prevailing at that time. Such complicating factors as ground garbage, automatic washers, detergents, softener wastes and so on had not made their appearance. To develop a new empirical relationship to include those factors would entail a tremendous amount of costly and time consuming field work. We are, however, investigating individual factors in the laboratory to determine their effect on soil clogging from which adjustment of the relationship may be made.

It would be logical to consider the causes of soil clogging under three general headings: physical, chemical and biological. Septic tank effluent can contribute to all three types of clogging. Actually, from preliminary studies it appears that biological activity does not cause soil clogging under effluent dosing conditions, but instead tends to reduce clogging caused by other factors. Laboratory soil cores packed with a variety of soils and dosed with effluent over a three-month period clogged in proportion to the amount of

suspended solids in the effluent. After a few weeks of dosing, biological activity appeared to reduce the rate of clogging. Furthermore, a disinfected effluent applied to cores showed a more rapid rate of clogging than normal effluent applied to identical cores. Apparently digestion taking place in the soil results in a net decrease in soil clogging.

A possible source of chemical type clogging lies in the use of commercial chemical compounds for cleaning septic tanks. Brand labels indicate that some of these cleaners contain caustic soda, and two of them by analysis were found to contain the equivalent of 95 per cent sodium hydroxide when computed as sodium hydroxide. Dramatic results were obtained when soil cores were dosed with effluent containing sodium hydroxide. At a pH of 10 and above soil clogging occurred almost immediately accompanied by a destruction of soil structure. Effluent from a 455-gallon tank registered a pH above 11.0 for five days after being dosed with 25 pounds of sodium hydroxide. A recommended dose of cleaner is 25 pounds for a 250-gallon tank.

Soil cores have also been dosed with effluent from a tank which received weekly salt additions, simulating water softener wastes. No appreciable difference in soil clogging between the salt effluent and a normal effluent were noted. In fact, there was some evidence that solids in the salt effluent caused less clogging than those in the normal effluent. There was, however, a definite breakdown of the soil structure in the cores dosed with salt effluent. In that stability of soil structure is an index of sustained soil permeability, such damage may be more important from the long time viewpoint than the short time percolation behavior noted above. Field examinations of soils in residential systems receiving softener wastes will be made at the first opportunity to determine the long range behavior.

The aspects of tank behavior under ground garbage loadings were discussed previously. There is definite evidence that septic tanks receiving ground garbage may require larger absorption fields. Dosing of sewage-garbage effluent to soil cores caused a more rapid rate of clogging than did the sewage-only effluent, both on a basis of equal length of time of dosing, and on a basis of an equal amount of suspended solids added. In order to maintain the same rate as cores receiving normal effluent, laboratory data indicates that the area of cores receiving ground garbage effluents would have to be increased by 20 to 35 per cent. I would like to emphasize, however, that this cannot be considered a final figure, as the results have been obtained on only four soil types and under laboratory dosing conditions. To develop a comprehensive figure will require investigation of the problem in the field. From these indications, if I were building a system for myself today, I would be inclined to increase its size by 50 per cent to provide for the inclusion of ground garbage waste.

Another factor to be considered is the relative effect of detergents as compared to soap. In preliminary experiments with detergent-effluent and soap-effluent solutions soil core clogging was more related to the concentration of suspended solids than to the soap or to the detergent. In later experiments, in order to remove the influence of suspended solids, soil cores were dosed with tap water-grease solutions to which detergents or soap had been added. These experiments produced startling results. Initially, percolation through both sets of cores was interfered with. However, after 30 days of dosing, the rate for the detergent cores started to increase and soon reached rates which were higher than those at the start. In the meantime, rates through the soap cores continued to decrease.

The increase in rate of the detergent cores seemed to be associated with surface tensions. When the solutions were added to the cores, their surface

tensions were all depressed by the surface active material in the soap or in the detergent. After the solutions had passed through the cores, their surface tensions were raised to about that of tap water, indicating that the surface active material was being removed by the soil. However, when the rates of the detergent cores increased, it was noted that the surface tensions of the detergent percolates were still depressed. Evidently the surface active material was no longer being removed, and the reduced surface tension of the solution was effective throughout the core. On the other hand, the percolate from the soap cores continued at about the value of tap water throughout the study.

I want to caution you that the foregoing results were obtained under laboratory conditions and with only one soil type. Furthermore, similar results were not obtained in preliminary experiments using effluent-detergent solutions. More laboratory and field studies will be undertaken on this subject at the first opportunity.

In closing, I should like to emphasize two thoughts which should be kept in mind in dealing with "septic tank systems." The first is that the septic tank is not a disposal system of itself, but is an important unit of a process in which the objective is the disposal of waste liquid into the ground. Soil, for waste disposal purposes, is a sensitive medium, not only sensitive to the heavy liquid loadings we place on it, but susceptible, also, to damage from abnormal changes in the waste being applied to it. We should keep this in mind, not only in considering septic tank design and operating factors, but also in connection with servicing procedures. The second thought is that while the development of factual information is of fundamental importance, it will fall short of its purpose if it is not applied to the design, installation, operation and servicing of each individual installation.